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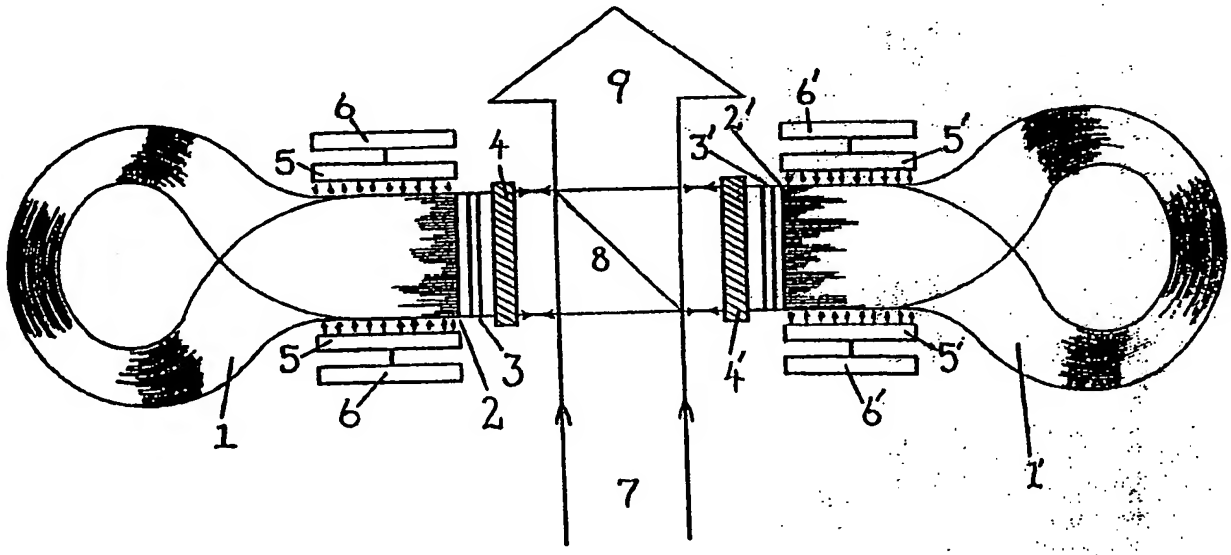
(54) Title: SCALEABLE, FIBRE LASER BUNDLE REGENERATIVE AMPLIFIER SYSTEM



(57) Abstract

This invention relates to a regenerative laser amplifier system consisting of two phase locked fibre bundle laser amplifiers (1) whose optically polished ends (2) are coupled via the microlens array (3) into the electro-optic switch (4). The said amplifiers are side excited using diode arrays (5) driven by pulsed power supplies (6). The input pulse (7) to be amplified is reflected in the said system via the polarised beam splitter (8) and becomes trapped in the system by being polarisation rotated through 90° by switch (4). After amplification to the required power level, the switching process is reversed and the amplified pulse is ejected as output beam (9). The invention has application in the industrial, defense and scientific fields where laser pulses of very high peak powers are required.

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Scaleable, Fibre Laser Bundle Regenerative Amplifier System

Field of the Invention

This invention relates to a scaleable, phase locked, regenerative amplifier system consisting of two looped, phased locked, fiber bundle laser amplifiers positioned output face to output face with a polarizing beam splitter positioned in between said faces and an electro-optic switch placed near each of the said faces. In the case where the doped core of said optical fibers are much less in diameter that the cladding thickness, a micro lens array is positioned between said output face and the electro-optic switch to match the emissions from each of the individual fiber cores into a parallel, phase locked laser beam. The injected polarized laser beam is reflected into the invention via the input face of a polarizing beam splitter and is directed through the electro-optic switch into the said fiber laser bundle from which it emerges in an amplified form and has its plane of polarization rotated a further 45° as it passes back through the still activated electro-optic cell. With a 90° shift in the orientation of its plane of polarization, the laser pulse then passes through the polarized beam splitter onto an identical looped fiber amplifier configuration whose electro-optic switch is not activated. The pulse is then trapped in the amplifier passing to and fro between its two end sections where it is amplifier further. When the required level of amplification has been achieved, the second electro-optic switch is activated and the amplified laser pulse is ejected out of the invention. The invention can be scaled to aperture diameters of more than on meter capable of emitting laser pulses in excess of

10^{15} watts peak power. The invention has applications in the industrial, scientific and defence fields whenever high peak power laser beams are required.

Summary of the Prior Art

Prior art regenerative amplifier systems are not scaleable to the high power level capabilities of which they should be capable of. Also, prior art regenerative amplifiers did not involve having lengths of gain media which could be rapidly excited during the transit time of the laser pulse undergoing amplification within those prior art systems.

The present invention overcomes the defects of prior art regenerative amplifiers by allowing the laser pulse to be amplified to spend a significant fraction of the transmit time within the laser gain medium which can be rapidly excited after being depleted of stored energy by the pulse amplifying process. Also, the invention is scaleable to large beam diameters exceeding one meter in diameter and more than 10^{15} watts in peak output power, a capability completely beyond prior art regenerative amplifier systems.

Background of the Invention

The amplification of laser pulses to high peak power levels has always presented a problem because no sooner than the problems ar solved at a given power lever when the next level up the power scale presents new problems.

In general, laser pulses are amplified through cascades of individual amplifiers of increasing cross-sectional area. In 1967, the inventor proposed (Applied Optics, USA, August 1967) the use of an exponential amplifier to amplify laser pulses to very high peak power levels in such a manner that the cross-section of the amplifier increased exponentially to maintain a constant flux density through the said amplifier.

This invention provides an alternative technology for the amplification of laser pulses to very high peak power levels using the regenerative amplifier approach where the laser gain medium is in the form of phase locked optical fibre bundles which are optically excited using arrays of laser diodes.

The invention amplifies an input laser pulse by first of all rotating its plane of polarisation through 90° thus trapping the said pulse between two activated laser amplifiers or a laser amplifier and a 100% reflecting mirror which can replace one of the said amplifiers. After the laser pulse has been amplified to the required power level, its plane of polarisation is changed again by 90° so that it can be emitted from the amplifier system via the rear face of the polarising beam splitter used to input the said pulse into the amplifier system originally.

The invention allows a laser pulse to be amplified to very high power levels by multiple passages through the same amplifiers rather than a cascade of amplifiers. In this way, only two large amplifiers or one large amplifier and a plane mirror are needed to boost the power of laser pulses to levels well in excess of 10^{15} watts peak. To handle such high power laser beams needs large

diameter optics and this requirement has held up the development of regenerative amplifiers in the past. With the advent of diode pumped fibre bundle lasers this situation is now changed with phase locked arrays of fibres and electro-optic switches providing the large scale optical structures necessary to handle such high laser pulse powers.

Summary of the Invention

It is an object of the invention to provide means of amplifying laser pulses to very high peak power levels using a minimal number of laser amplifiers.

Another object of the invention is to provide laser amplifiers in the form of phase locked fiber bundles, the optically polished ends of the individual fibres from said bundles being coupled to arrays of micro lenses which collinate the fibre output beams into a phase-locked, large diameter laser beam.

It is an object of the invention to provide phase locked, fibre bundle laser beam amplifiers which are side excited with the output light from laser diode arrays.

Another object of the invention is to provide additional end pumping of the laser fibre bundle amplifiers in the case where the said amplifiers are double ended.

It is an object of the invention to provide laser amplifiers of scaleable diameters achieved by adding more fibres to said fibre bundle forming said amplifiers.

Another object of the invention is to provide electro-optic switch arrays which are able to switch a phase locked array of

laser beams forming the main input and output beams.

It is an object of the invention to provide fibre bundle amplifiers with each amplifier composed of a single bundle of fibres.

Another object of the invention is to provide fibre bundle amplifiers with each amplifier composed of groups of fibre bundle amplifiers whose output apertures are positioned an hexagonal array exhibiting a matching pattern for the electro-optic switch array.

Brief Description of the Drawings

A better understanding of the invention may be obtained from the following considerations taken in conjunction with the accompanying drawings which are not meant to limit the scope of the invention in any way.

In Figure 1, we show the basic unit of the invention whilst in Figure 2 we show the format of the invention which represents an assembly of the basic units shown in Figure 1 and able to amplify phase locked input laser beams to very high power levels. In Figure 3, we show a straight bundle configuration of the present invention.

Detailed Description of the Invention

In Figure 1, numeral 1 indicates a bundle of single mode optical fibers doped with lasing ions. Numeral 2 indicates the array of optically polished end faces of the individual fiber loops. Numeral 3 indicates a micro lens array whilst numeral 4 indicates an lectro-optic switch to rotate the plane of polarization of the laser

beam being amplified in the invention. Numeral 5 indicates an array of semiconductor light sources or similar light sources emitting narrow spectral bandwidth pump light which matches the absorption bands of laser fiber 1. Numeral 6 indicates the power supply for diode array 5.

In Figure 1, numeral 7 indicates the input laser pulse to be amplified by the invention whilst numeral 8 indicates a polarized beam splitter which directs the input pulse 7 into the invention to pass through activated electro-optic switch 4, through the micro lens array 3 and into the looped laser fiber bundle 1 which is where it is amplified and spatially filtered.

On its return passage through 4, the plane of polarization is rotated a further 45° so the pulse passes through polarizer 8 into an identical end section which it enters via a deactivated electro-optic switch 4. The pulse is then amplified as it transverse the end amplifiers. When the required amplification level has been attained, electro-optic switch 4 is activated rotating the plane of polarization of the pulse to its original orientation so that it is reflected off polarizer 8 as output beam 9.

In Figure 2, numeral 10 indicates a group of phase locked laser beams to be amplified in the invention. Numeral 11 indicates a polarized beam splitter which directs the input beam 10 into the invention. Beam 10 then passes through an array of electro-optic switches indicated by numeral 12, which matches the group of laser beams in input beam 10. The activated array 12 rotates the plane of polarization of each of the laser beams forming the phase locked input beam 10, by 45° . Each of said beams in phase locked

beam 10 is then passed through the array of micro lenses 3 and matched to the cores of the fiber ends 2 making up fiber bundles 1 which are stacked together, each of the said bundles 1 being optically excited with diode arrays indicated by numeral 13, which are powered by the supply indicated by numeral 14. Numeral 15 indicates a mirror to reflect any excitation light from diode array 13 back into each of the fiber bundles 1. On passing through the electro-optic switch array 12 after being amplified in the fiber bundle array, the plane of polarization of the laser beam is rotated a further 45° so that it passes through the polarized beam splitter 11 to pass through the inactivated electro-optic switch array 12 into an identical end amplifier fiber bundle assembly where the laser beam is amplified further. The pulse is then amplified as it transverses the invention and when the required amplification has been attained, electro-optic switch array 12 is activated, rotating the plane of polarization of the said laser beam to its original state so that said beam is ejected out of the invention as the output beam indicated by numeral 16.

In Figure 3, numeral 17 indicates a fiber laser bundle with optically polished, mirrored ends indicated by numeral 18 through which additional excitation light generated by the diode array indicated by numeral 19 whose electrical power supply is indicated by numeral 20 enters the laser gain medium 17.

The invention has application in the industrial, medical, defence and the research and development fields with particular relevance to the laser fusion and laser radar fields.

I claim,

1. A scalable laser beam regenerative amplifier system which can amplify a low powered input laser pulse to over 10^{15} watts peak power, said system consisting of:

a) Two, phase locked, looped fibre bundle laser amplifiers whose output apertures face each other so that the output of one can act as the input for the other.

b) Laser diode arrays used to side pump the said fibre bundle amplifiers so that they are excited prior to the passage of said laser pulses.

c) A microlens array for collinating the outputs of the individual fibre ends forming the output aperture of said amplifiers so as to form a phase locked laser beam which then passes through an electro-optic switch which rotates the plan or polarisation through an angle of 90.

d) A polarised beam splitter positioned between the two said amplifiers such than an input pulse directed into the said regenerative amplifier system is able to traverse the said polariser without loss after being rotated through an angle of 90 via polarisation through said optical switch.

e) Two optical switches, one placed either side of said polariser, end of the said switches rotating the plane of polarisation of the passing laser pulse by 90 initially to trap the said pulse within said amplifier and subsequently to allow said laser pulse to be ejected from said system after allowing required

level of amplification.

2. A system as claimed in claim 1 where the single fibre amplifiers are replaced with an array of laser fibre amplifier bundles, the output aperture of which are placed in a hexagonal ring.

3. A system as claimed in claim 1 where the fibre bundle amplifier is double ended, said fibres being optically excited via the end faces.

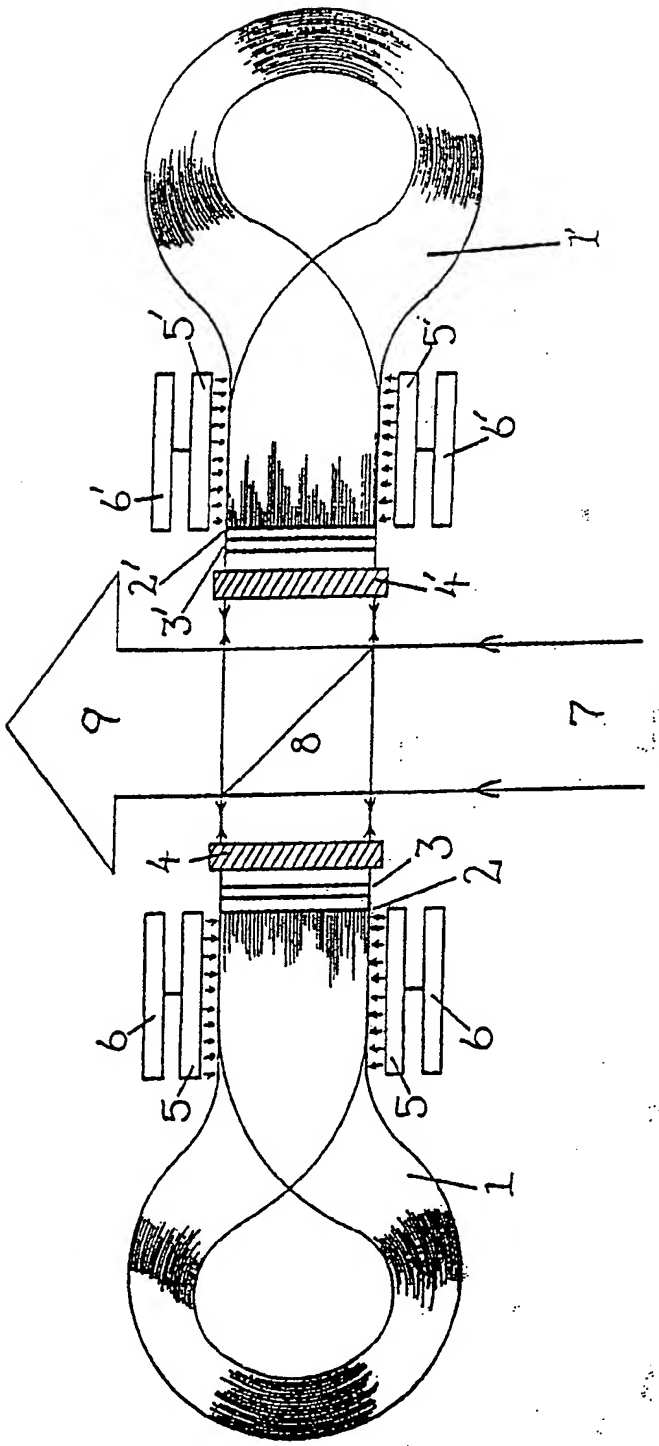

Figure 1

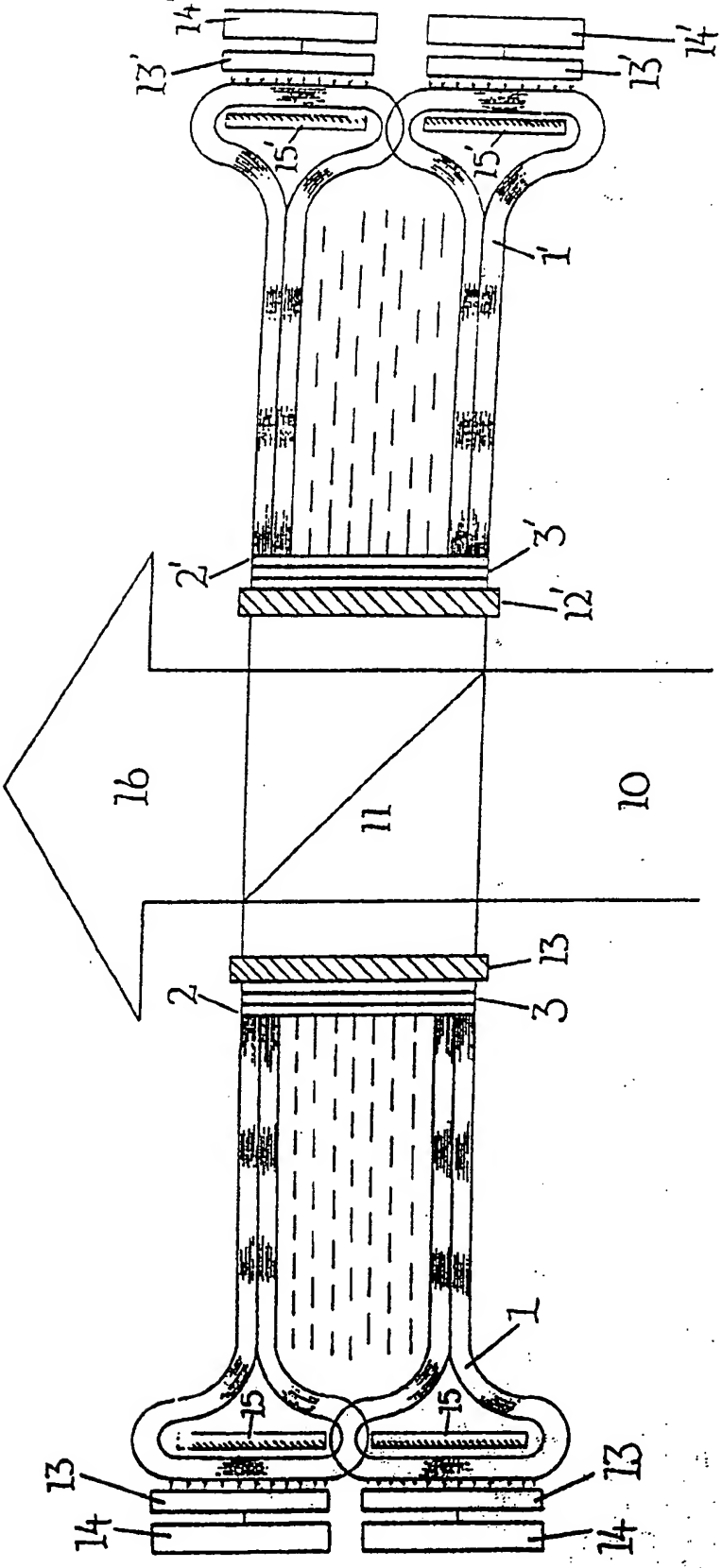

Figure 2

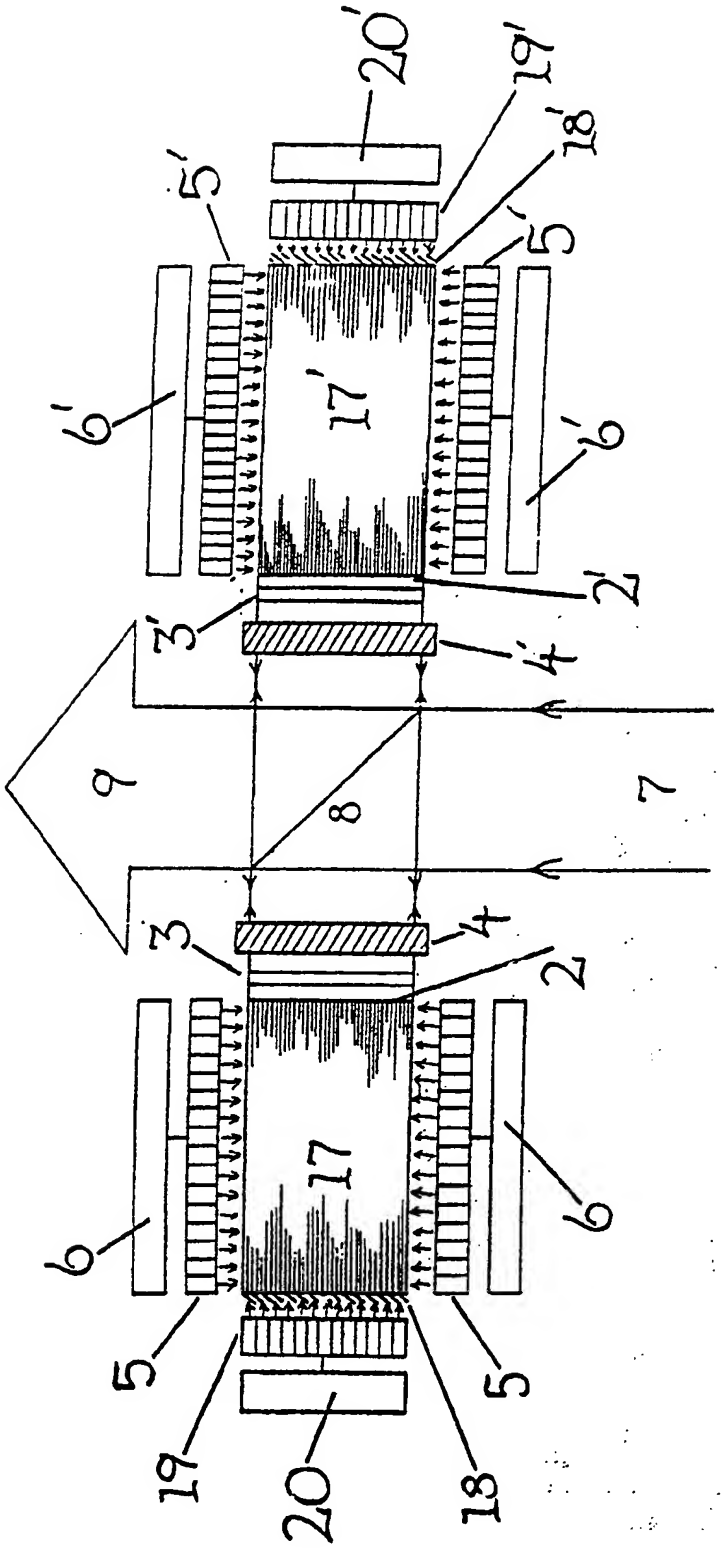

Figure 3

INTERNATIONAL SEARCH REPORT

International Application No. PCT/AU 90/00460

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) 6

According to International Patent Classification (IPC) or to both National Classification and IPC

Int. Cl.[5] H01S 3/08, 3/094, 3/07, 3/23

II. FIELDS SEARCHED

Minimum Documentation Searched 7

Classification System	Classification Symbols
IPC	H01S 3/06, 3/07, 3/08, 3/23

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched 8

AU : H01S

III. DOCUMENTS CONSIDERED TO BE RELEVANT 9

Category*	Citation of Document, 11 with indication, where appropriate, of the relevant passages 12	Relevant to Claim No 13
A,P	WO,A, 90/00320 (PHASED ARRAY LASERS PTY LTD) 11 January 1990 (11.01.90)	
A,P	WO,A, 89/11172 (PHASED ARRAY LASERS PTY LTD) 16 November 1989 (16.11.89)	
A	AU,A, 38742/85 (HUGHES TECHNOLOGY PTY LTD) 22 August 1985 (22.08.85)	
A	US,A, 3471215 (SNITZER) 7 October 1969 (07.10.69)	

* Special categories of cited documents: 10

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
8 January 1991 (08.01.91)	11 January 1991
International Searching Authority	**Signature of Authorized Officer**
Australian Patent Office	W.J. MAJOR

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON
INTERNATIONAL APPLICATION NO. PCT/AU 90/00460

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report	Patent Family Members	
WO 9000320	AU 39655/89	EP 393163
WO 8911172	AU 35601/89	EP 378598
AU 38742/85	GB 2154364	US 4682335
US 3471215	DE 1539653	GB 1155372

END OF ANNEX